



# Buckyball Nucleation of HiPco Tubes

Lyndon B. Johnson Space Center, Houston, Texas

The purpose of this innovation is to enhance nucleation of single-wall nanotubes (SWNTs) in the HiPco process, selectively producing 10,10 tubes, something which until now has not been thought possible.

This is accomplished by injecting  $C_{60}$ , or a derivative of  $C_{60}$ , solubilized in supercritical  $CO_2$  together with a transition metal carbeneal co-catalyst into the HiPco reactor. This is a variant on the "supercritical" disclosure.  $C_{60}$  has never

been used to nucleate carbon nanotubes in the gas phase.

$C_{60}$  itself may not have adequate solubility in supercritical  $CO_2$ . However, fluorinated  $C_{60}$ , e.g.,  $C_{60}F_{36}$ , is easy to make cheaply and should have much enhanced solubility.

*This work was done by Richard E. Smalley of Rice University for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Rice University*

*Office of Technology Transfer – MS 705*

*P.O. Box 1892*

*Houston, TX 77251-1892*

*Phone No. (713) 737-6143*

*Refer to MSC-24134-1, volume and number of this NASA Tech Briefs issue, and the page number.*



# Adjusting Permittivity by Blending Varying Ratios of SWNTs

**High, intermediate, and low permittivity values can be tailored for specific applications.**

*Lyndon B. Johnson Space Center, Houston, Texas*

A new composite material of single-walled carbon nanotubes (SWNTs) displays radio frequency (0 to 1 GHz) permittivity properties that can be adjusted based upon the nanotube composition. When varying ratios of raw to functionalized SWNTs are blended into the silicone elastomer matrix at a total loading of 0.5 percent by weight, a target real permittivity value can be obtained between 70 and 3. This has particular use for designing materials for microwave lenses, microstrips, filters, resonators, high-strength/low-weight electromagnetic interference (EMI) shielding, antennas, waveguides, and low-loss magneto-dielectric products for applications like radome construction.

High permittivities contain higher ratios of raw SWNTs, while lower permittivity values contain higher ratios of functionalized SWNTs. The functionalized SWNTs contain *t*-butyl aryl groups that allow for good dispersion in the composite due to favorable interactions between the functional groups and the matrix. The functionalized SWNTs are prepared using diazonium chemistry with raw, HiPco-produced SWNTs and *t*-butyl aniline. Various ratios of raw functionalized SWNTs totaling 0.5 percent by weight (to the elastomer matrix) composition of

nanotubes (weight does not include the added functional groups) are first dispersed in chloroform via bath sonication. The dispersion is then solvent-blended in chloroform with Part A of the NuSil silicone elastomer R-2625. After the solvent is removed through flowing air, the mixture is dried further in a vacuum oven at 60 °C. Part B of the NuSil silicone elastomer R-2615 (10 percent by weight to Part A) is added to the sample and mixed until an even distribution is achieved. The sample is allowed to evacuate in a vacuum desiccator for approximately one hour to remove any air bubbles that are trapped within it. The sample is then thermally cured at ≈200 °C for approximately two hours. At this point, the sample is ready to be tested for dielectric permittivity measurements.

One limitation in this material occurs when there is a variance in the SWNTs that is produced via the HiPco process. If the tubes vary from batch to batch, it is possible that the electric properties of resulting composites may be affected. This, in turn, could also affect the uniformity of the resulting SWNTs that are functionalized. The best consistency in data trends is observed when the composites are made from the same batch of raw and functionalized SWNTs.

It is expected that, in order for the materials described above to be used in the field of microwave radar devices, other additives and components most likely will be incorporated, depending on the intended application. Some examples may include a magnetic component for magneto-dielectric materials, as well as changing the type of polymer host matrix. In addition, metallic particles could be added (1 to 100 weight percent) to bring up the permeability to ranges that equal the permittivity.

*This work was done by James M. Tour, Jason J. Stephenson, and Amanda Higginbotham of Rice University for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Rice University  
Office of Technology Transfer MS 705  
P.O. Box 1892  
Houston, TX 77251-1829  
Phone No.: (713) 348-6188  
E-mail: techtran@rice.edu*

*Refer to MSC-24344-1, volume and number of this NASA Tech Briefs issue, and the page number.*



# Polyolefin-Based Aerogels

**These aerogels can be used for thermal insulation and radiation shielding in apparel, aircraft, race car insulation, and military and recreation tents.**

*Lyndon B. Johnson Space Center, Houston, Texas*

An organic polybutadiene (PB) rubber-based aerogel insulation material was developed that will provide superior thermal insulation and inherent radiation protection, exhibiting the flexibility, resiliency, toughness, and durability typical of the parent polymer, yet with the low density and superior insulation properties associated with the aerogels. The rubbery behaviors of the PB rubber-based aerogels are able to overcome the weak and brittle nature of conventional inorganic and organic aerogel insulation materials. Additionally, with higher content of hydrogen in their structure, the PB rubber aerogels will also provide inherently better radiation protection than those of inorganic and carbon aerogels. Since PB rubber aerogels also exhibit good hydrophobicity due to their hydrocarbon molecular structure, they will provide better performance reliability and durability as well as simpler, more economic, and environmentally friendly production over the conventional silica or other inorganic-based aerogels, which require chemical treatment to make them hydrophobic.

Inorganic aerogels such as silica aerogels demonstrate many unusual and useful properties. There are several strategies to overcoming the drawbacks associated with the weakness and brittleness of silica aerogels. Development of the flexible fiber-reinforced silica aerogel composite blanket has proven one promising approach, providing a conve-

niently fielded form factor that is relatively robust toward handling in industrial environments compared to silica aerogel monoliths. However, the flexible silica aerogel composites still have a brittle, dusty character that may be undesirable, or even intolerable, in certain applications. Although the cross-linked organic aerogels such as resorcinol-formaldehyde (RF), polyisocyanurate, and cellulose aerogels show very high impact strength, they are also very brittle with little elongation (i.e., less rubbery). Also, silica and carbon aerogels are less efficient radiation shielding materials due to their lower content of hydrogen element.

The present invention relates to maleinized polybutadiene (or polybutadiene adducted with maleic anhydride)-based aerogel monoliths and composites, and the methods for preparation. Hereafter, they are collectively referred to as polybutadiene aerogels. Specifically, the polybutadiene aerogels of the present invention are prepared by mixing a maleinized polybutadiene resin, a hardener containing a maleic anhydride reactive group, and a catalyst in a suitable solvent, and maintaining the mixture in a quiescent state for a sufficient period of time to form a polymeric gel. After aging at elevated temperatures for a period of time to provide uniformly stronger wet gels, the microporous maleinized polybutadiene-based aerogel is then obtained by

removing interstitial solvent by supercritical drying. The mesoporous maleinized polybutadiene-based aerogels contain an open-pore structure, which provides inherently hydrophobic, flexible, nearly unbreakable, less dusty aerogels with excellent thermal and physical properties. The materials can be used as thermal and acoustic insulation, radiation shielding, and vibration-damping materials.

The organic PB-based rubber aerogels are very flexible, no-dust, and hydrophobic organics that demonstrated the following ranges of typical properties: densities of 0.08 to 0.255 g/cm<sup>3</sup>, shrinkage factor (raerogel/rtarget) = 1.2 to 2.84, and thermal conductivity values of 20.0 to 35.0 mW/m-K.

*This work was done by Je Kyun Lee and George Gould of Aspen Aerogels, Inc. for Johnson Space Center. For more information, download the Technical Support Package (free white paper) at [www.techbriefs.com/tsp](http://www.techbriefs.com/tsp) under the Materials & Coatings category.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Aspen Aerogels, Inc.  
30 Forbes Road, Building B  
Northborough, MA 01532  
Phone No.: (508) 691-1111  
E-mail: [info@aerogel.com](mailto:info@aerogel.com)*

*Refer to MSC-24213-1, volume and number of this NASA Tech Briefs issue, and the page number.*



# Concept for Hydrogen-Impregnated Nanofiber/Photovoltaic Cargo Stowage System

*Lyndon B. Johnson Space Center, Houston, Texas*

A stowage system was conceived that consists of collapsible, reconfigurable stowage bags, rigid polyethylene or metal inserts, stainless-steel hooks, flexible photovoltaic materials, and webbing curtains that provide power generation, thermal stabilization, impact resistance, work/sleeping surfaces, and radiation protection to spaceflight hardware and crewmembers.

Providing materials to the Lunar surface is costly from both a mass and a volume standpoint. Most of the materials that will be transferred to other planets or celestial bodies will not be returned to the Earth. In developing a plan to reconfigure pressurized logistics modules, it was determined that there was a requirement to be able to utilize the interior volume of these modules and trans-

form them from "Logistics Modules" to "Storage/Living Quarters."

Logistics-to-living must re-utilize stowage bags and the structures that support them to construct living spaces, partitions, furniture, protective shelters from solar particle events, galactic cosmic radiation, and workspaces. In addition to reusing these logistics items for development of the interior living spaces, these items could also be reused outside the habitable volumes to build berms that protect assets from secondary blast ejecta, to define pathways, to stabilize high traffic areas, to protect against dust contamination, to secure assets to mobility elements, to provide thermal protection, and to create other types of protective shelters for surface experiments.

Unique features of this innovation include hydrogen-impregnated nanofibers encapsulated in a polyethylene coating that act as radiation shielding, flexible solar collection cells that can be connected together with cells from other bags via the webbing walls to create a solar array, and the ability to reconfigure each bag to satisfy multiple needs.

*This work was done by Kriss J. Kennedy, Larry David Toups, and Robert L. Howard of Johnson Space Center; Alan S. Howe of NASA's Jet Propulsion Laboratory; and Jason Eric Poffenberger of Wyle Laboratories. For more information, download the Technical Support Package (free white paper) at [www.techbriefs.com/tsp](http://www.techbriefs.com/tsp) under the Mechanics/Machinery category. MSC-24624-1*



# Engineered Multifunctional Surfaces for Fluid Handling

**These processes create antibacterial and hydrophilic properties on metallic and polymeric surfaces.**

*Lyndon B. Johnson Space Center, Houston, Texas*

Designs incorporating variations in capillary geometry and hydrophilic and/or antibacterial surface properties have been developed that are capable of passive gas/liquid separation and passive water flow. These designs can incorporate capillary grooves and/or surfaces arranged to create linear and circumferential capillary geometry at the micro and macro scale, radial fin configurations, micro holes and patterns, and combinations of the above.

The antibacterial property of this design inhibits the growth of bacteria or the development of biofilm. The hydrophilic property reduces the water contact angle with a treated substrate such that water spreads into a thin layer atop the treated surface.

These antibacterial and hydrophilic properties applied to a thermally conductive surface, combined with capillary geometry, create a novel heat exchanger capable of condensing water from a humid, two-phase water and gas flow onto the treated heat exchanger surfaces, and passively separating the condensed water from the gas flow in a reduced gravity application.

The overall process to generate the antibacterial and hydrophilic properties includes multiple steps to generate the two different surface properties, and can be divided into two major steps.

Step 1 uses a magnetron-based sputtering technique to implant the silver atoms into the base material. A layer of silver is built up on top of the base material. Completion of this step provides the antibacterial property. Step 2 uses a cold-plasma technique to generate the hydrophilic surface property on top of the silver layer generated in Step 1. Completion of this step provides the hydrophilic property in addition to the antibacterial property.

Thermally conductive materials are fabricated and then treated to create the antibacterial and hydrophilic surface properties. The individual parts are assembled to create a condensing heat exchanger with antibacterial and hydrophilic surface properties and capillary geometry, which is capable of passive phase separation in a reduced gravity application.

The plasma processes for creating antibacterial and hydrophilic surface properties are suitable for applications where water is present on an exposed surface for an extended time, such that bacteria or biofilms could form, and where there is a need to manage the water on the surface. The processes are also suitable for applications where only the hydrophilic property is needed. In particular, the processes are applicable to condensing heat exchangers (CHXs), which benefit

from the antibacterial properties as well as the hydrophilic properties. Water condensing onto the control surfaces of the CHX will provide the moist conditions necessary for the growth of bacteria and the formation of biofilms. The antibacterial properties of the base layer (silver) will mitigate and prevent the growth of bacteria and formation of biofilms that would otherwise reduce the CHX performance. In addition, the hydrophilic properties reduce the water contact angle and prevent water droplets from bridging between control surfaces. Overall, the hydrophilic properties reduce the pressure drop across the CHX.

*This work was done by Chris Thomas and Yonghui Ma of Orbital Technologies Corporation, and Mark Weislogel for Johnson Space Center. For more information, download the Technical Support Package (free white paper) at [www.techbriefs.com/tsp](http://www.techbriefs.com/tsp) under the Materials & Coatings category.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Orbital Technologies Corp.*

*1212 Fourier Drive*

*Madison, WI 53717*

*Refer to MSC-24496-1/502-1, volume and number of this NASA Tech Briefs issue, and the page number.*



# Developing Physiologic Models for Emergency Medical Procedures Under Microgravity

*Lyndon B. Johnson Space Center, Houston, Texas*

Several technological enhancements have been made to METI's commercial Emergency Care Simulator (ECS) with regard to how microgravity affects human physiology. The ECS uses both a software-only lung simulation, and an integrated mannequin lung that uses a physical lung bag for creating chest excursions, and a digital simulation of lung mechanics and gas exchange. METI's patient simulators incorporate models of human physiology

that simulate lung and chest wall mechanics, as well as pulmonary gas exchange.

Microgravity affects how O<sub>2</sub> and CO<sub>2</sub> are exchanged in the lungs. Procedures were also developed to take into account the Glasgow Coma Scale for determining levels of consciousness by varying the ECS eye-blinking function to partially indicate the level of consciousness of the patient. In addition, the ECS was modified to provide various levels of pulses

from weak and thready to hyper-dynamic to assist in assessing patient conditions from the femoral, carotid, brachial, and pedal pulse locations.

*This work was done by Nigel Parker and Veronica O'Quinn of Medical Education Tech, Inc. for Johnson Space Center. For more information, download the Technical Support Package (free white paper) at [www.techbriefs.com/tsp](http://www.techbriefs.com/tsp) under the Bio-Medical category. MSC-23922-1*